LEACH Improvement Based on Ant Colony Optimization and Energy Balance

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Abstract

As a low-power adaptive hierarchical network protocols for wireless sensor networks, LEACH assumes that all nodes can transmit data with the sink node directly and cluster head nodes transfer the information to the sink node in multi-hop fashion, therefore it is significant for using ant colony optimization algorithm to converge multi-hop path from the cluster head nodes to the sink node. In the selection of cluster head nodes, with LEACH protocol it is not been considered that the residual energy of the nodes themselves and how to distribute the cluster head nodes in the network, so we introduce the energy factor and density factor, and select the secondary cluster head from the cluster heads after the introduction of the neighbor nodes. The MATLAB simulation results show that taking advantage of the improved algorithm the time of death of the first node is extended and network performance and balance of node energy consumption are improved more effectively in the networks, which require of high coverage.

Keywords

LEACH; Multi-hop; Ant Colony Optimization; Energy Balance

Introduction

LEACH (Low-Energy Adaptive Clustering Hierarchy) (Heinzelman et al., 2000) is a low-power adaptive hierarchical routing protocol that is designed for WSN (Wireless Sensor Networks). In LEACH the basic idea is that each node is balanced to share the energy consumption of the network by circulating clustering, so that it can balance the energy consumption of the network and extend the lifetime of the network. There have been many improved algorithm for LEACH till now. LEACH-C algorithm (Rahmanian et al., 2011) is one of the most classic LEACH improved algorithm, and the center control mechanism in the selected cluster head is introduced to reduce the energy consumption. *p*LEACH (Yektaparast et al., 2012) on the basis of LEACH-C, through the study of the sector of the entire network division, in every sector in select high energy cluster head nodes act as the cluster head. LEACH-D (Pawar et al., 2012) is introduced the residual energy and density of nodes in the cluster head node selected on the threshold $T(n)$, so that selecting the cluster head is more rationalization. LEACH-m (Zhang et al., 2012) division is carried out on the network according to the cluster head and base station distance of non-uniform cluster partition. HEED (Younis et al., 2004) protocol is introduction of residual energy in the cluster heads selection and introduction of certain constraints to speed up the clustering speed and solve uneven clustering. DEEC algorithm (Gou et al., 2010) considered the heterogeneity of network and node residual energy and increased the probability of high energy node election of cluster heads. References introduced the energy parameters with parameter $T(n)$ in LEACH algorithm, reduced the probability of elected cluster head node low energy. This paper presents the improved algorithm has two aspects, one is proposed to improve the energy factor and density factor after the introduction of the neighbor nodes, another to place in the neighbor node cluster head election that multistage cluster after the initial cluster preferred. Besides, the cluster head to transmission from the sink to the ordinary single-hop multi-hop, increasing the size of LEACH applications and using the improved ant colony algorithm for multi-hop path optimization.

The Improved Algorithm

Improved Ant Colony Optimization for Multi-hop Path

In this article, we take the improved ant colony algorithm for multiple hops path optimization, and data transmission manner using selective multi-hop path. Based on LEACH, multi-hop routing needs the classical ant colony algorithm to do the following improvements.

Because this article cited the ant colony algorithm optimization, and convergence of cluster nodes is the distance between nodes, the ant is not climb up all nodes. In order to prevent pheromone decay due to the ants don't go to choose to climb path, we introduce

the global update mechanism. Combined with ant system and the characteristics of minimum system of the two largest global updates, the pheromone updating formula is:

$$\tau_{ij}(t+1) = (1-\rho)\tau_{ij}(t) + \rho\Delta\tau_{ij}(t,t+1) \tag{1}$$

heuristic factor instead as follows:

$$\eta_{ij} = \begin{cases} 1/d_{ij}^2, & d_{ij} < d_0 \\ 1/d_{ij}^4, & d_{ij} \geq d_0 \end{cases} \tag{2}$$

$$d_0 = \sqrt{\frac{E_{friss}}{E_{amp}}} \tag{3}$$

where E_{friss} is a power amplifier using energy loss coefficient under free-space model circuit amplifier, and E_{amp} is the loss of power amplifier using multi-path attenuation model energy consumption coefficient of the amplifier.

Improved Cluster Head Selection

We first introduce the neighbor nodes. Neighbor nodes should calculate the optimal number of clusters. The optimal number of clusters is derived from consulting the reference (Kumar et al., 2011). This paper studies the multi-hop LEACH network. The communication path of the cluster head to the gathering node is optimized by ant colony algorithm, so the calculation of the optimal cluster head number is different with the single hop networks. Assuming d_{toBS} is the distance between the cluster head node and multi-hop path next hop cluster head node, the ideal situation is the first cluster of data transmission compared to the free-space data transmission attenuation model. So the optimal number of cluster head after the reduction formula is as follows:

$$H = \sqrt{\frac{N}{2\pi}} \times \frac{M}{d_{toBS}} \tag{4}$$

Where H is the optimal number of cluster heads and is closely related with the regional coverage area. The larger the area of the region is, the more the first few optimal cluster there, the more empathy nodes, the more optimal cluster head. In fact, if there are much more clusters, cluster heads can jump the more paths, as compared to the random distribution of cluster heads, the number of cluster nodes to the cluster heads and jump distance is not fixed , in order to reduce energy loss $d_{toBS} \leq d_0$. However, the use of multi-hop transmission is not transmitting data between nodes using multi-hop or hops the more energy efficient. With the increase in the number of jumps, it will increase network latency and packet loss rate of data transmission will increase. Therefore, the number of jumps should be appropriate. Jump from the optimal value d_0, and then we can find the optimal number of clusters, i.e. the optimal number of cluster heads. Then we can determine the optimal number of clusters, namely the optimal number of cluster heads. The average size of each cluster occupies is M^2/H, assume that the first cluster in the center of the cluster area, cluster area is round, the size of the radius R is $\sqrt{M^2/2\pi H}$. We define the neighbor node that the neighbor of node i is all the nodes that communication distance with node i is smaller than the R.

In wireless sensor networks, we need to use information to minimize the node itself energy node. A node can easily get the number of neighbor nodes and their residual energy itself. We can know the approximate location of the node density region by number of neighbors of a node. The more neighboring nodes, the greater the area of the node density, otherwise the density is smaller.

Considering taking the preferred cluster nodes during the current residual energy, increasing the probability of remaining large energy elected nodes, the introduction of energy regulation parameters is as follows:

$$E(n) = \frac{E_{sur}(n)}{E_a} \tag{5}$$

where $E_{sur}(n)$ is the value of the node n current residual energy, E_a is the expected average energy all nodes in the network, its size is as follows:

$$E_a = E_t \frac{1 - r / r_{\max}}{N} \tag{6}$$

where E_t is the sum of all nodes when the network initial energy, r is the current round, $r_{\max}$ is expected for the network can be carried out round number, N is the number of all initial network nodes.

All nodes in the network broadcast a message after the node can receive the information of neighbor node around, which will have corresponding RSSI values. According to the value, we can determine the number

of its neighbor nodes, thereby introducing density adjusting parameters:

$$D(n) = \frac{Neighbor(n) \times H}{N_r} \tag{7}$$

where $Neighbor(n)$ is a node number of neighbor nodes, N_r is the number of the current round number all live node, H is the optimal number of cluster head.

We add the energy and density adjustment of silver to the election of cluster head nodes threshold, join an adjusted is as follows:

$$T(n) = \begin{cases} [\dfrac{p}{1 - p(r \bmod (1/p))}] \times R\,, & n \in G \\ 0, & \text{otherwise} \end{cases} \tag{8}$$

$$R = c_1 \times E_a(n) + c_2 \times D(n), \quad c_1 + c_2 = 1 \tag{9}$$

In order to balance energy consumption, this paper select cluster head again. We let the resulting cluster head node with its neighbors to compete. Second was elected as the cluster head node close to the optimal number of cluster heads. Secondary cluster head election will be responsible for communication with the sink node, the first elected cluster head node in the cluster is responsible for collecting the data. Select the improved cluster head flow chart as shown in Fig. 1.

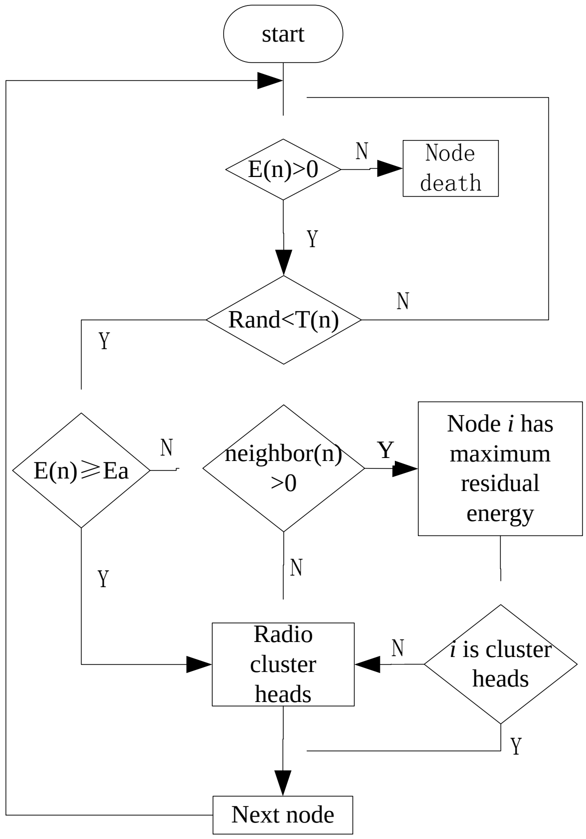

FIG. 1 THE FLOWCHART OF SELECTING THE CLUSTER HEATS

Simulation and Analysis

Energy Simulation Model

This is taken with the literature (Heinzelman et al., 2000) model of the same power, the sending node and the receiving node when the distance *d*, the transmitter sends data *k* bit energy to be consumed:

$$E_{TX}(k,d) = \begin{cases} E_{elec} \times k + E_{friss} \times k \times d^2, & d \le d_0 \\ E_{elec} \times k + E_{amp} \times k \times d^4, & d \ge d_0 \end{cases} \tag{10}$$

receiving node energy consumption:

$$E_{RX}(k) = E_{elec} \times k \tag{11}$$

data fusion energy consumption required to:

$$E_{fuse}(k) = E_{fuse} \times k \tag{12}$$

where, E_{elec} is the power transmitting and receiving unit, E_{fuse} is the power consumption of data fusion unit, when the transmission distance is greater than d_0, we using multi-path fading model, when the transmission distance is less than d_0, we using a free-energy model.

Experimental Results and Analysis

We used MATLAB as the simulation software. All experimental parameters were set with reference to the Table 1.

TABLE 1 EXPERIMENTAL PARAMETERS

Parameters (*unit*)	**Values**
Initial energy of sensor nodes (*J*)	0.5
Free space signal amplification coefficient (*pJ/bit/M²*)	10
Signal amplification coefficient for multi-path fading channel (*pJ/bit/M⁴*)	0.013
Energy consumption for sending the data (*J/bit*)	50×10^{-9}
Energy consumption for receiving the data (*J/bit*)	50×10^{-9}
Maximum transmission distance (*m*)	87.7
The biggest *r* max cycles	3500

Fig. 2 is the survive nodes changes over time curve of 100 nodes in the area of 100×100, sink node is located in regional centers. Fig. 3 is the survive nodes changes over time curve of 500 nodes in the area of 200×200, sink node is located in the origin. From the comparison of two figures can be seen that in a small area within the scope of the improved algorithm is better than LEACH and DEEC, the death of the first node delays about 20 rounds than LEACH-m, the effect is better than LEACH-m, but after the region to expand, LEACH-m not as good as LEACH itself, the

improved algorithm is superior to other algorithms, the network node energy balance, resulting in the death of almost time node, greatly extend the time of death of the head node.

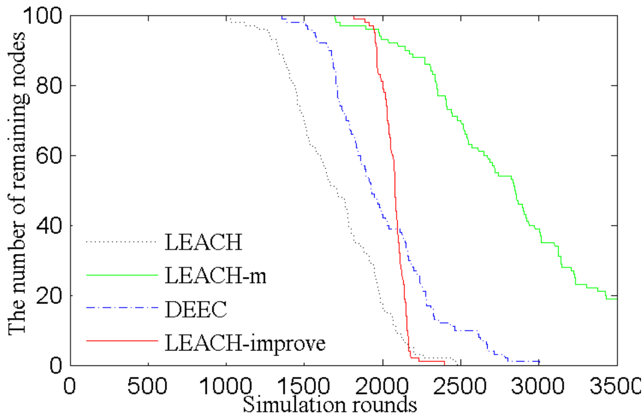

FIG. 2 CONTRAST THE REMAINING POWER FOR 100 NODES IN 100×100

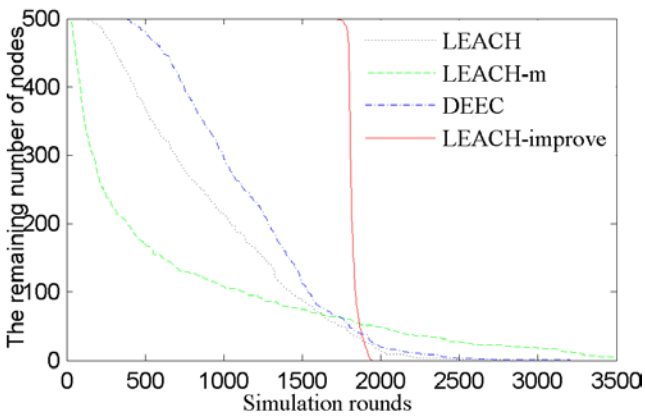

FIG. 3 CONTRAST THE REMAINING POWER FOR 500 NODES IN 200×200

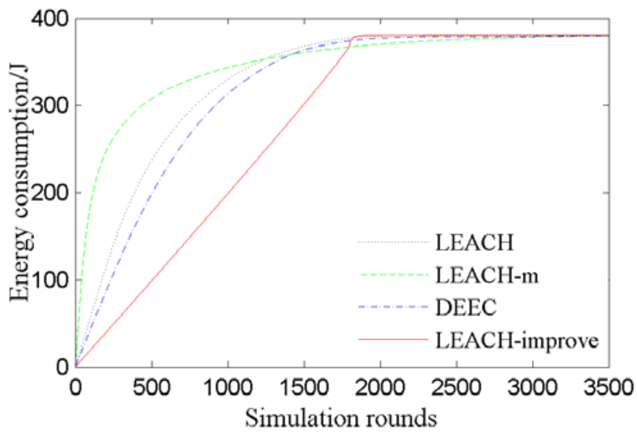

FIG. 4 CONTRAST THE NODES POWER CONSUMPTION FOR 500 NODES IN 200×200

Fig. 4 for the changing curve between the node energy consumption, that energy consumption significantly improved algorithm is superior to other algorithms within 2000 rounds. Fig. 5 for the network data throughput, obvious LEACH-m is superior to other algorithms, but its energy consumption is large, and the improved algorithm is better than that of LEACH and DEEC. According to the first multi-hop optimal cluster computing, the optimal cluster of 500 nodes alived in the area of 200×200 should be the value of 20.

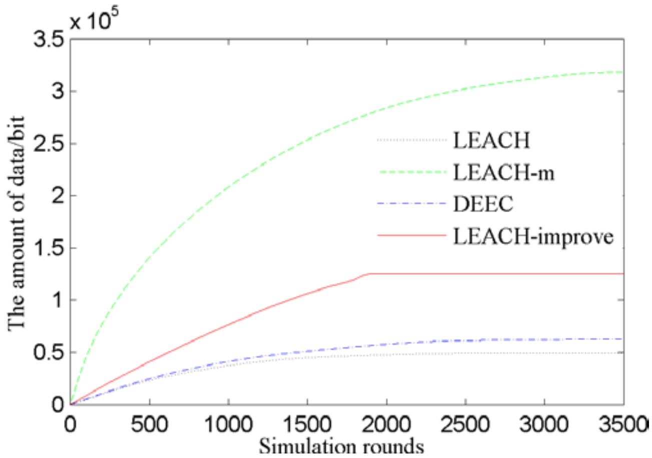

FIG. 5 CONTRAST THE AMOUNT OF DATA TRANSFERRED FOR 500 NODES IN 200×200

The value of the green line in Fig.6 near optimal cluster head, it meets the design requirements.

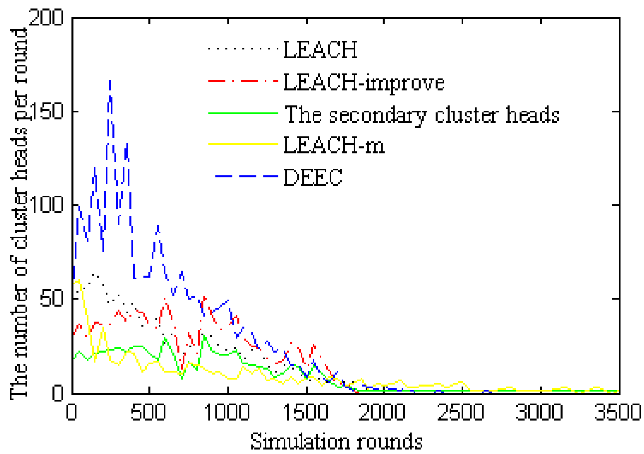

FIG. 6 CONTRAST THE NUMBER OF CLUSTER HEADS FOR 500 NODES IN 200×200

Conclusions

In this paper, we proposed some improvements for LEACH algorithm, and introduce the energy and density adjustment factor. The improved algorithm can effectively balance the energy consumption of nodes in the network and extend the time of death of the first node in the network. The network coverage area requires many obvious advantages of network. The improved ant colony algorithm is applied to LEACH, making LEACH no longer limited to a single-hop network and having a wider range of applications.

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